Prospects of Flavour Studies at the ILC

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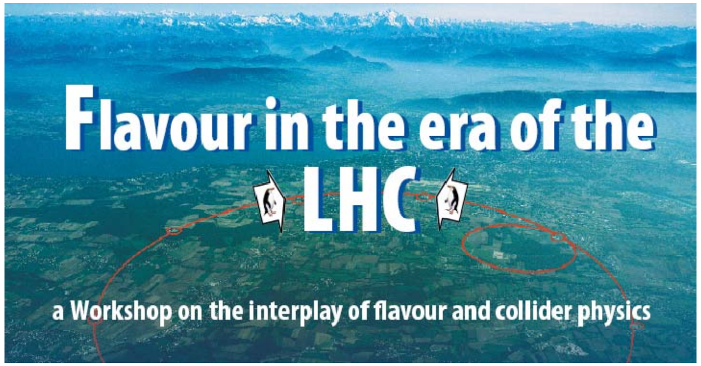
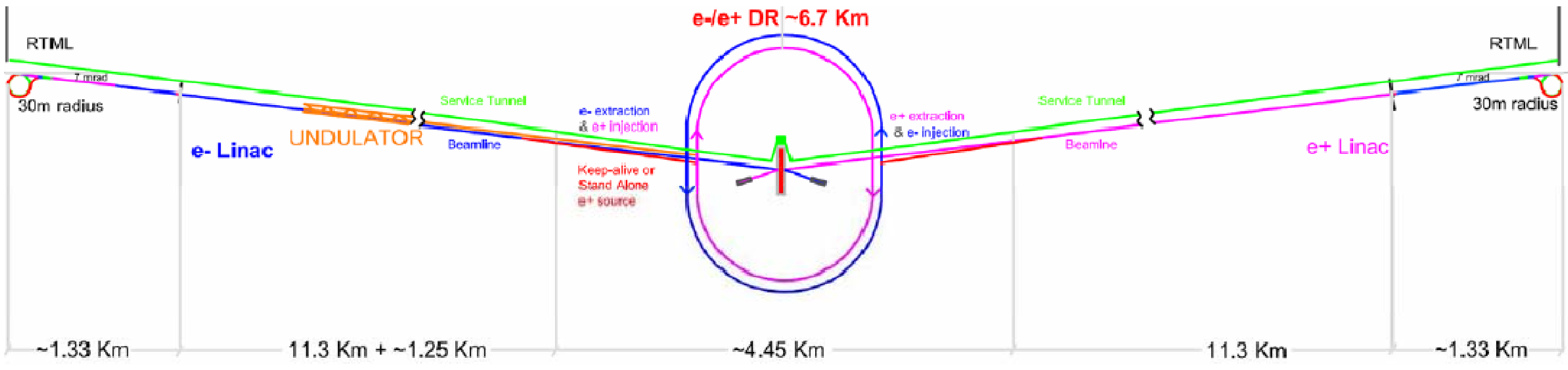


Outline

- The ILC project
- Electroweak symmetry breaking
  - Higgs bosons
- Supersymmetry
  - sleptons
  - gauginos
  - light stop
  - reconstructing supersymmetry
- Dark matter and colliders
  - neutralinos & gravitinos
- Conclusions

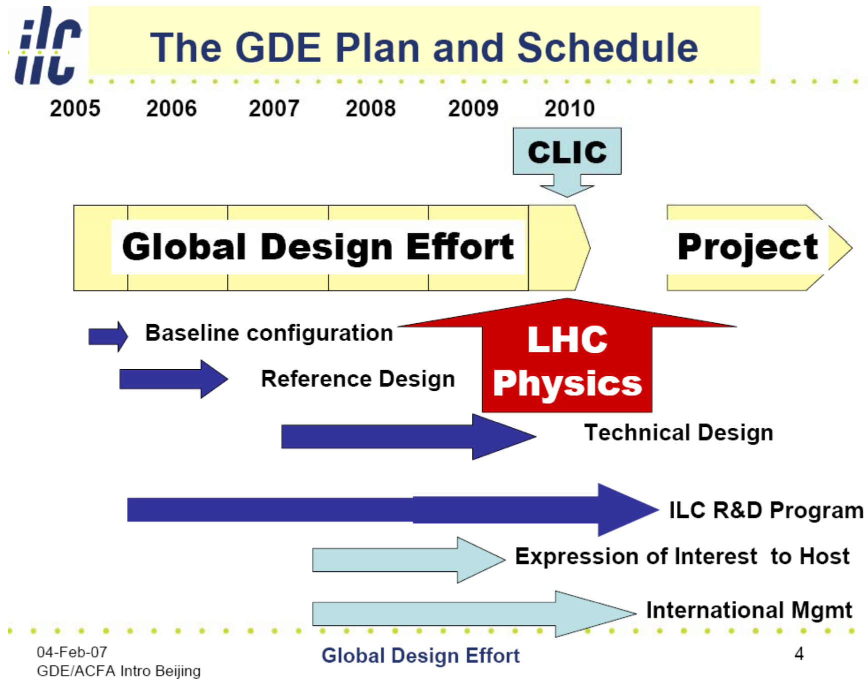
The ILC project



Reference Design Report (draft)

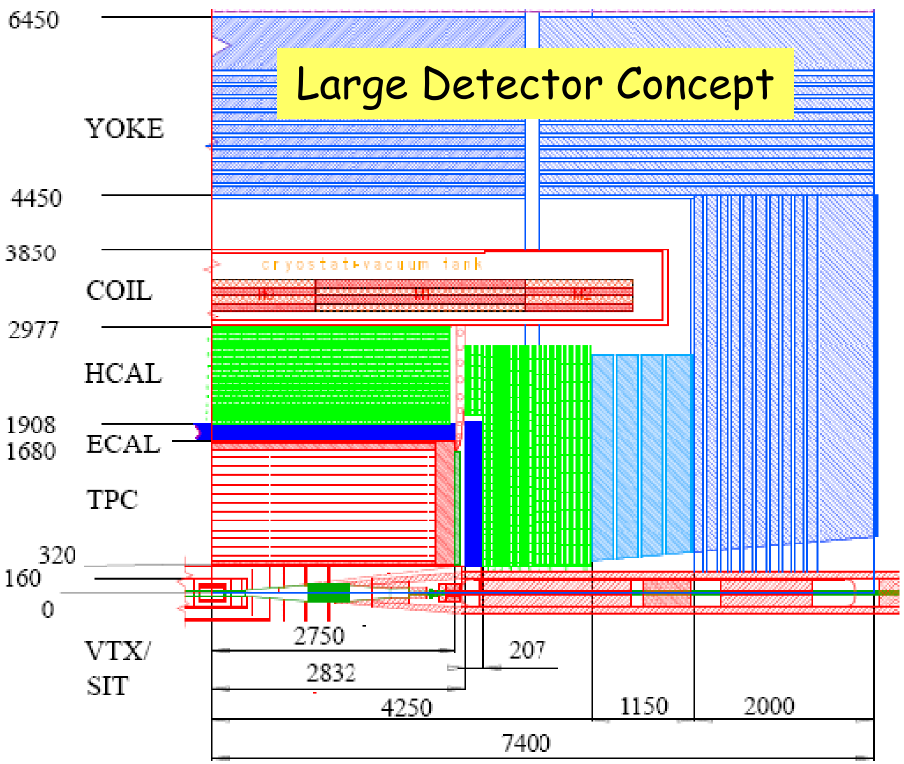
released on 8 February 2007

$\sqrt{s}$	500 GeV upgradeable to 1 TeV
U	31.5 MV/m
Length	31 km
Rate	5 Hz à 1 ms, 2625 bunches
Lumi	2×10^{34} cm^{-2} s^{-1} or 200 fb^{-1}/year
Polarisation	e^-: 0.80 / e^+: 0.60
Options	e^+e^-, e^-e^-, $\gamma\gamma$, $e\gamma$, GigaZ

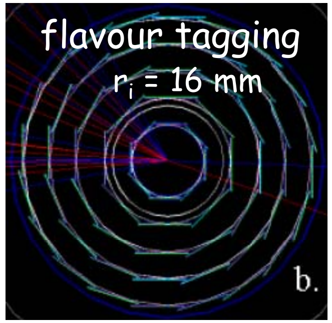


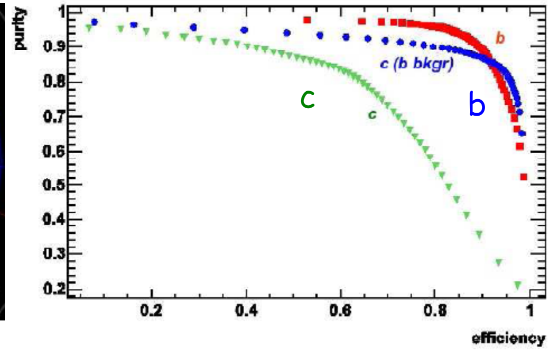
Detector & particle ID

LDC, GLD
SiD, 4th



h, μ, e	**TPC**	$\delta(1/p_t) = 5 \cdot 10^{-5}\,\mathrm{GeV}^{-1}$
c, q, τ	**VTX**	$\delta(R\phi) = 5 \oplus 10/p_t\ \mu\mathrm{m}$
e, γ	**ECAL**	$\delta E/E = 0.1/\sqrt{E[\mathrm{GeV}]}$
h, n, K_L^0	**HCAL**	$\delta E/E = 0.5/\sqrt{E[\mathrm{GeV}]}$
jets	**PFA**	$\delta E/E = 0.3/\sqrt{E[\mathrm{GeV}]}$

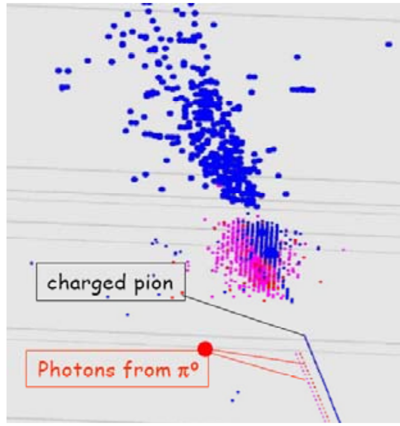


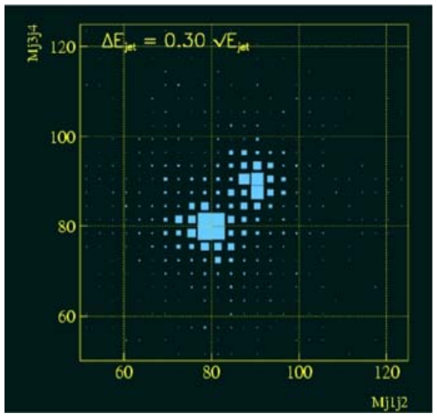


Imaging Calorimeter

Particle Flow

τ(250 GeV)→ρν





Energy Flow

ννWW & ννZZ @ 800 GeV

Why do we need the ILC?

For any new discovery at the LHC

Higgs, supersymmetry, extra dimensions …

we need to measure precisely the properties of the complete particle spectrum

masses, decay widths, spin, couplings, mixings, quantum numbers, cross-sections …

We want to unravel the basic, underlying theory

e.g. symmetry breaking mechanism, unification, *CPV, LFV,* R_PV …

Higgs	h H, A, $H^{\pm}$		
sparticles	neutralinos/charginos	KK states	γ_i, Z_i, W_i
	sleptons, squarks		l_i, q_i,
LSP	neutralino, gravitino, sneutrino	LKP	KK photon

➔ **Such a programme can only be achieved with the ILC as precision instrument, complementary to the LHC**

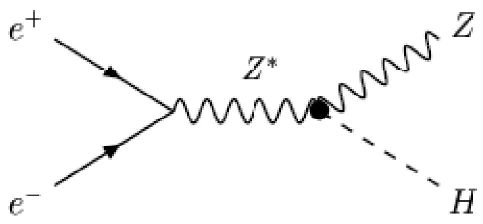
Higgs ID

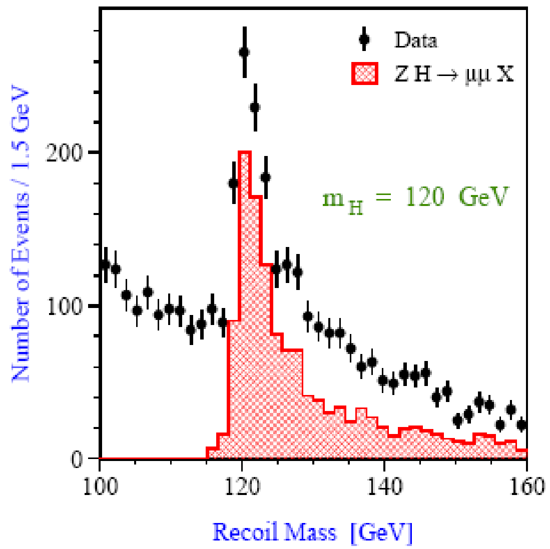
Higgs-strahlung

$e^+e^- \rightarrow ZH$

large rate ~10^4 @ 500 GeV

clean environment





Higgs identifiaction

via recoil mass from **$Z \rightarrow l^+l^-$, qq**

Higgs decay modes

H → ff, VV, gg, invisible

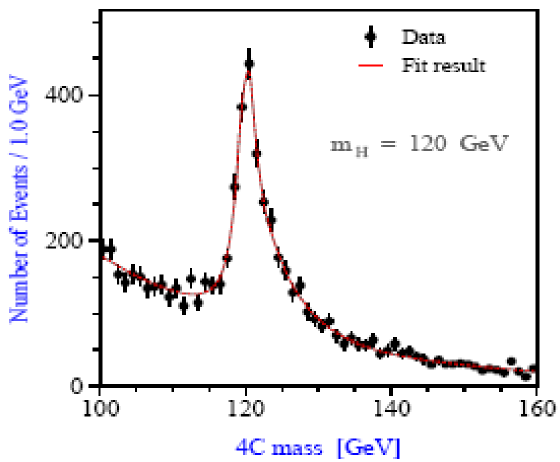
bias free Br measurements

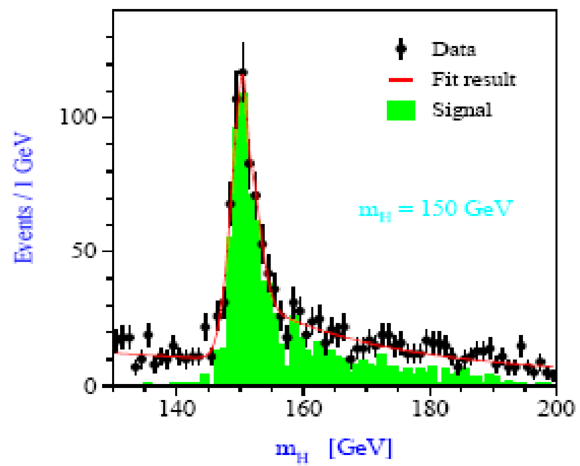
Higgs mass

kinematic 4C/5C fits using

leptonic and hadronic Z decays

+ Higgs → bb, WW decays





δm ~ 40 - 70 MeV

Higgs spin & parity

Spin $e^+e^- \to H\,Z$

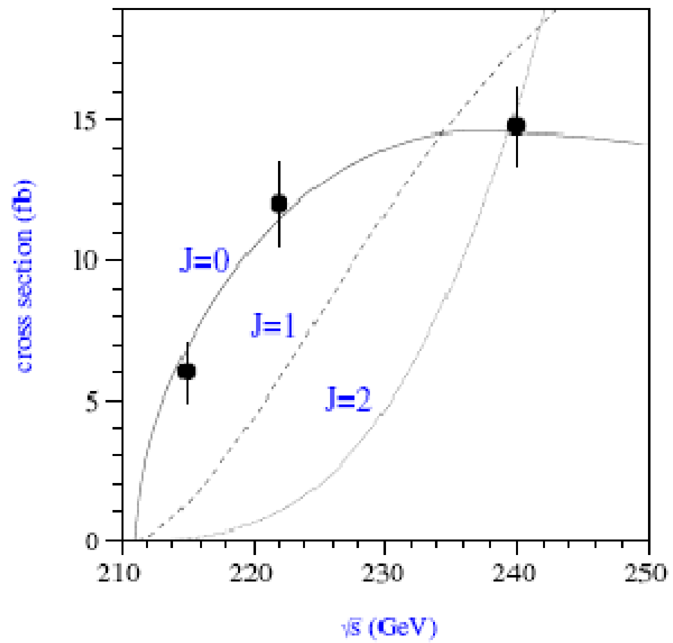
threshold excitation $\sigma \sim \beta$ ➔ $J^P = 0^+$ ($0^-, 1^-, 2^+, \ldots$ slower rise with $\beta^{n>1}$)

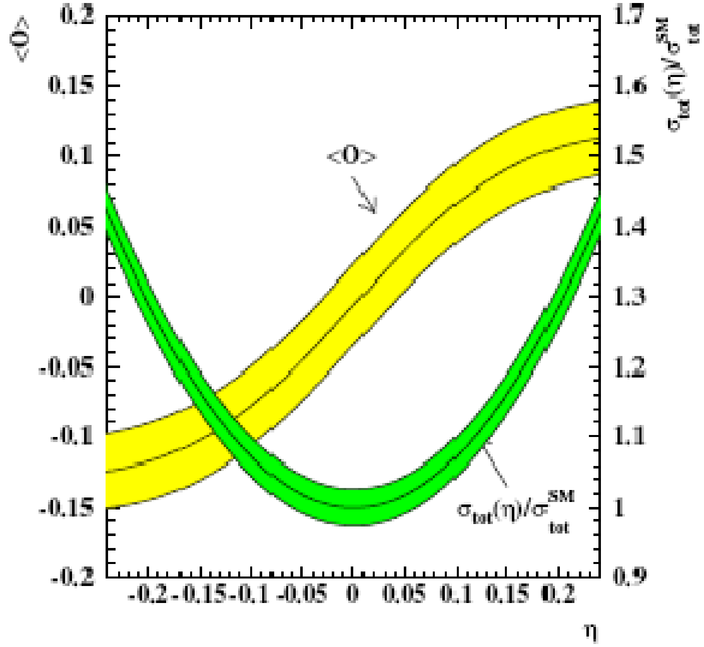
angular distribution $d\sigma/d\cos\Theta \sim \sin^2\Theta$ (very different from AZ, ZZ)

Parity

CP even / CP odd mixing η, CP odd observable **<O>**

$M = M_{HZ} + \eta\, M_{AZ}$ → asymmetry in diff. cross section ~ **cosΘ**



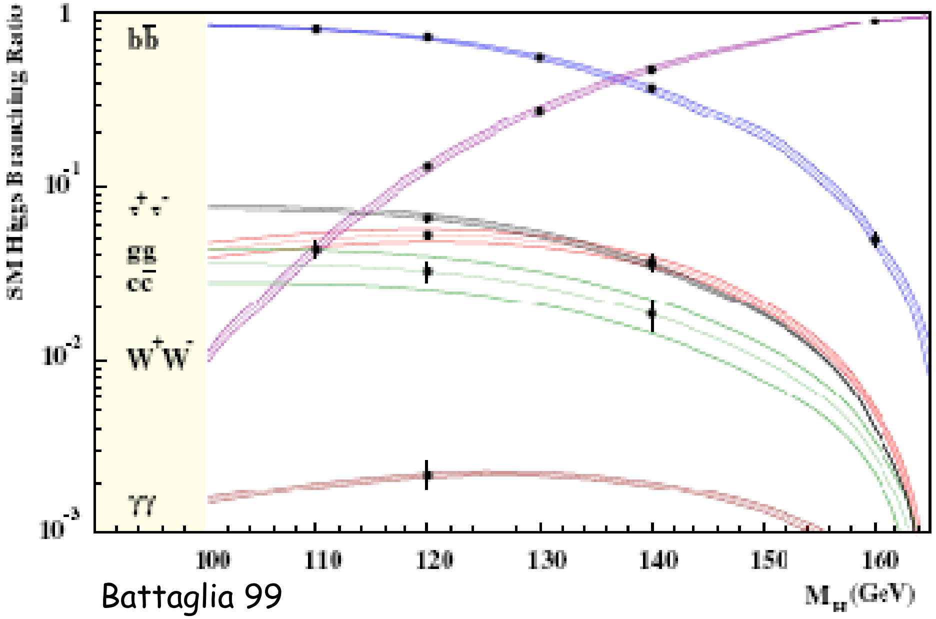


Higgs decay widths & couplings

Higgs decay widths

accurate determinations of Br's provide comprehensive test of Higgs mechanism in the SM, any deviations probe parameters of an extended Higgs sector

e.g. $B_{WW}/B_{\tau\tau}$ sensitive to M_A



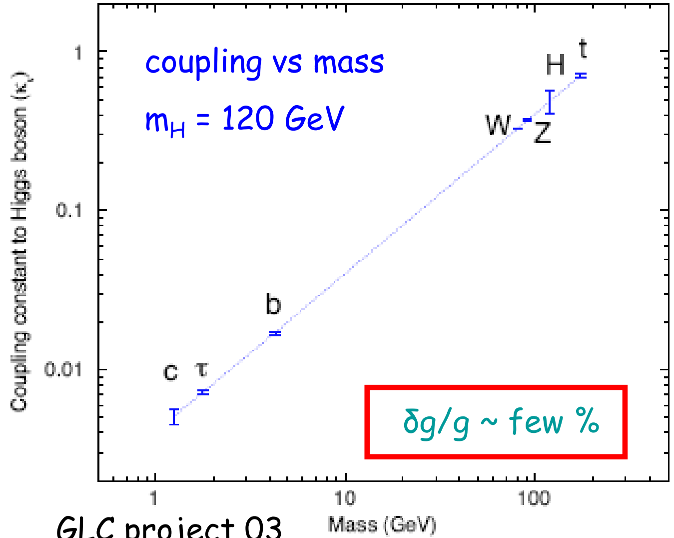
Battaglia 99

Higgs couplings

model independent determination using cross sections of Higgs-strahlung and WW fusion and branching ratios

$g_{Hff} = m_f/v, \; g_{HVV} = 2m^2_V/v$

$e^+e^- \to ZH$	inclusive	$g(HZZ)$ from σ_{HZ}
$e^+e^- \to ZH$	$H \to bb$	$BR(bb)$
$e^+e^- \to \bar{\nu}\nu H$	$H \to bb$	$g(HWW)$ from σ_{WW}/BR_{bb}
$e^+e^- \to ZH$	$H \to WW, bb, \tau\tau, cc$	$g(Hbb, \tau\tau, cc)$ from $BR_{()}/BR_{WW}$
$e^+e^- \to t\bar{t}H$	...	$g(Htt)$



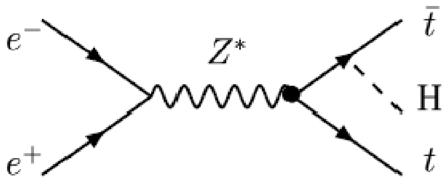
GLC project 03

Higgs couplings

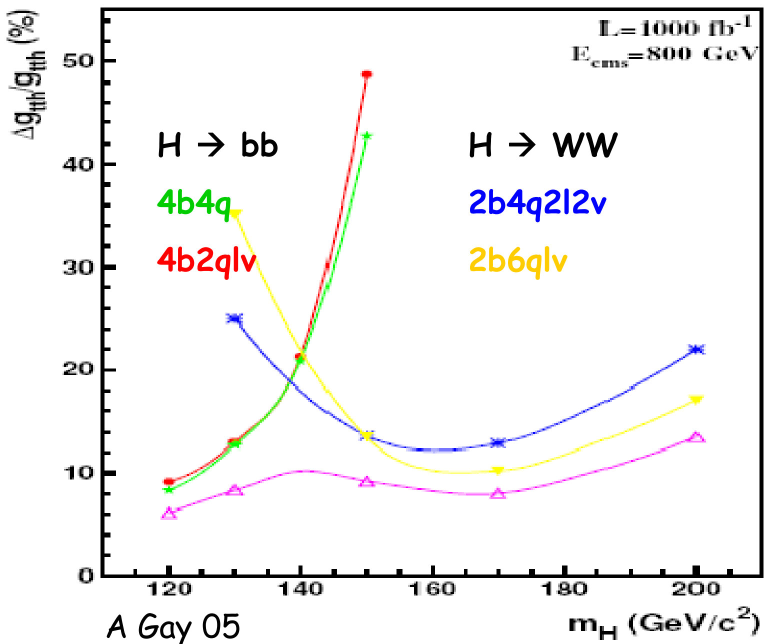
Higgs-top Yukawa coupling

$e^+e^- \rightarrow ttH \rightarrow$ 4b2W, 2b4W

t → W b, H → bb, WW



b tag, NN analysis
σ ~ 2 fb @ 800 GeV



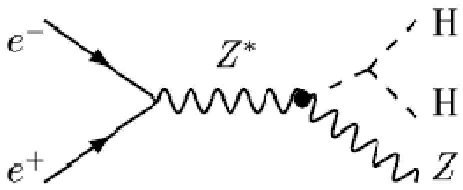
A Gay 05

Triple Higgs self-coupling

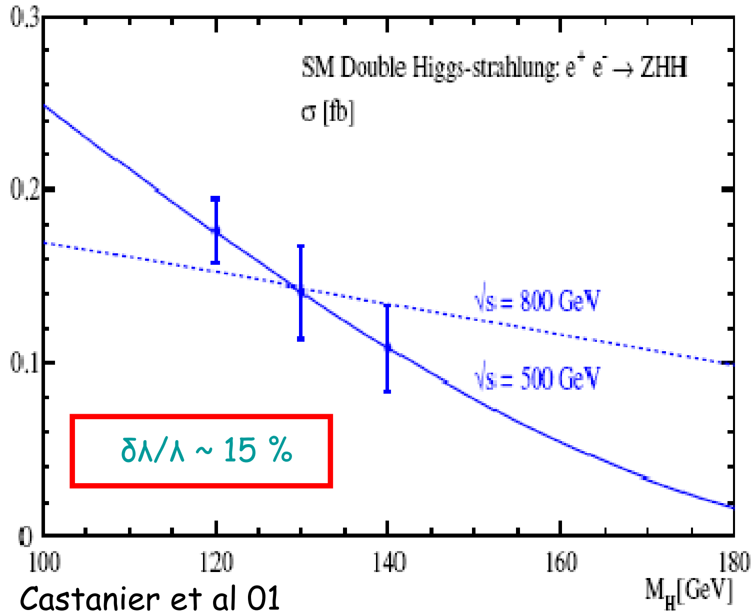
$e^+e^- \rightarrow HHZ \rightarrow$ 4b2q + 4b2l

→ unique opportunity for ILC

crucial for shape of Higgs potential



low σ, b tagging
+ NN analysis



Castanier et al 01

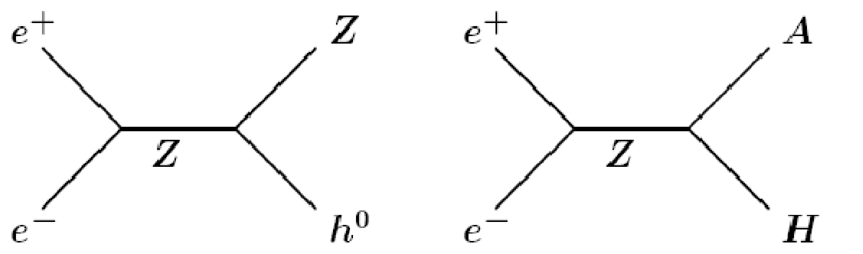
Higgs bosons in supersymmetry

Production — decoupling regime

light Higgs — $e^+e^- \to Zh$

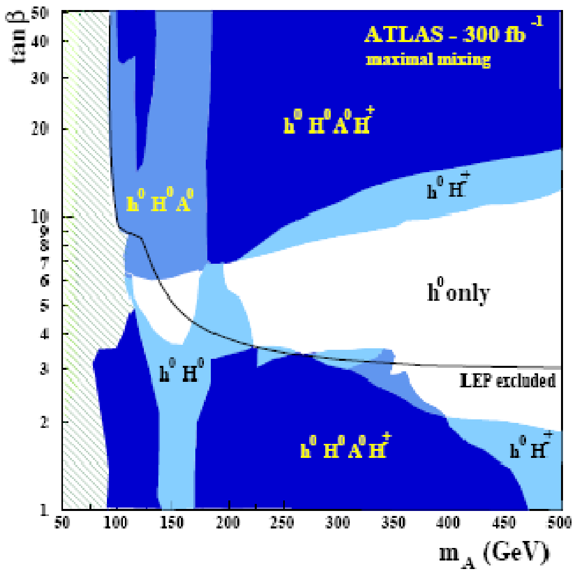
heavy Higgs — $e^+e^- \to AH,\ H^+H^-$

h SM like, H and A ~degenerate

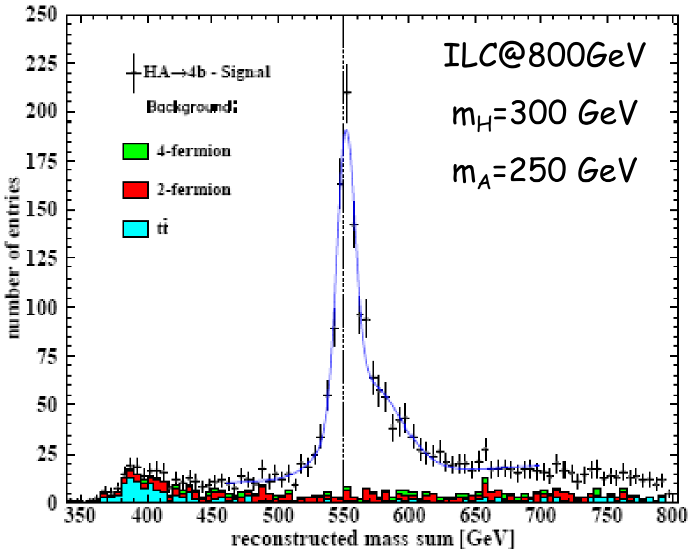


Filling blind LHC wedge — in tan β / m_A parameter space

LHC

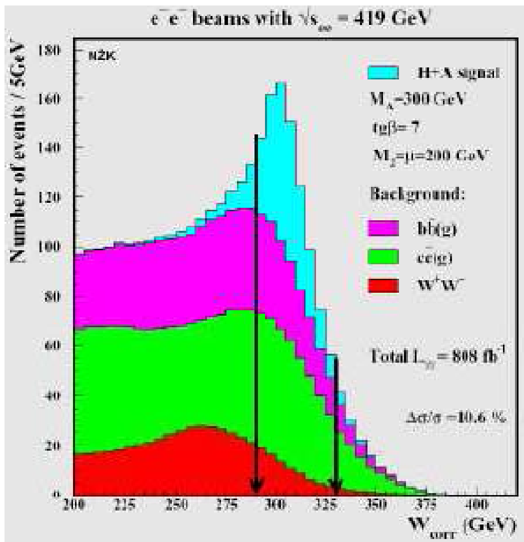


$e^+e^- \to HA \to bb\ bb$



Desch et al 04

$\gamma\gamma \to H/A \to bb$



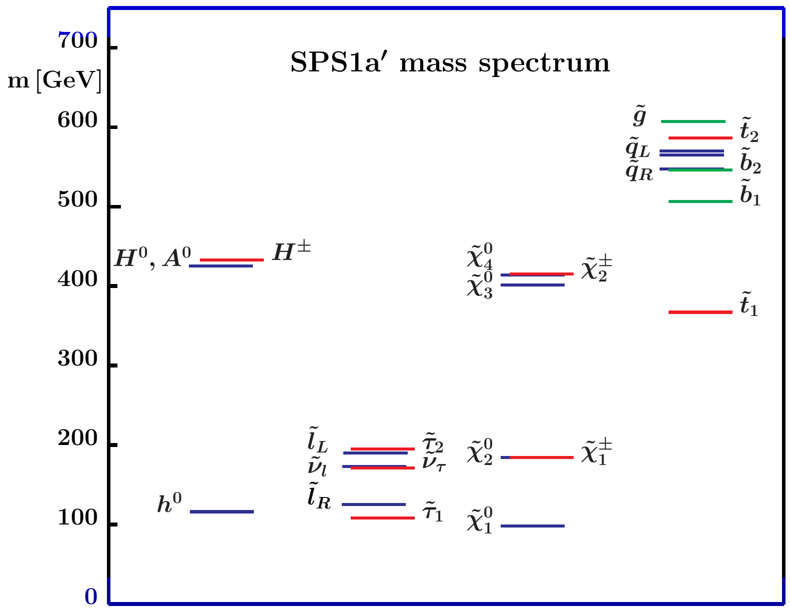
Niezurawski etal 05

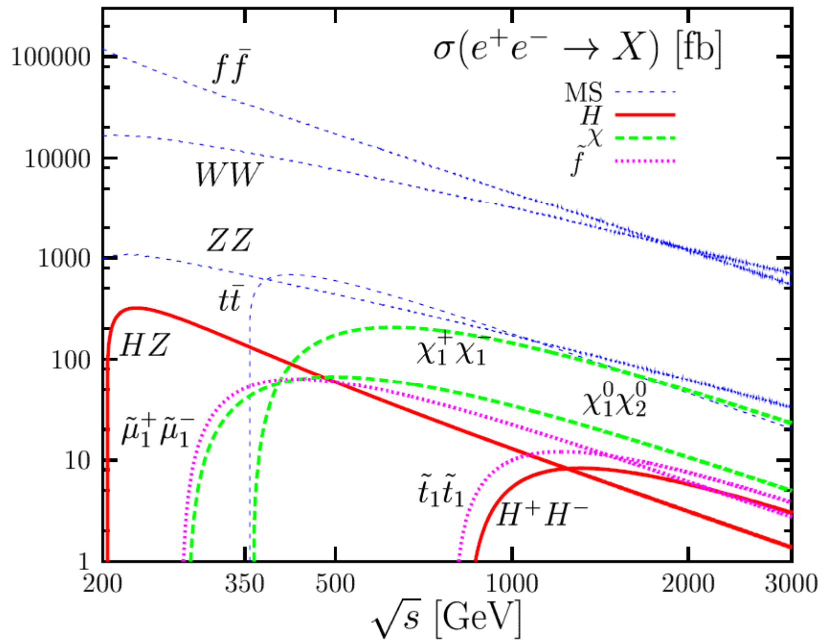
Exploring supersymmetry

- **Production of non-colored sleptons, neutralinos, charginos, light stop**
- **Select exclusive *reactions*, bottom-up exploration**
- **Polarisation: enhance signal, suppress background**
- **Model independent analysis**

SPS 1a' mSUGRA benchmark

favourable for LHC & ILC





Slepton masses

- Energy spectrum, end points

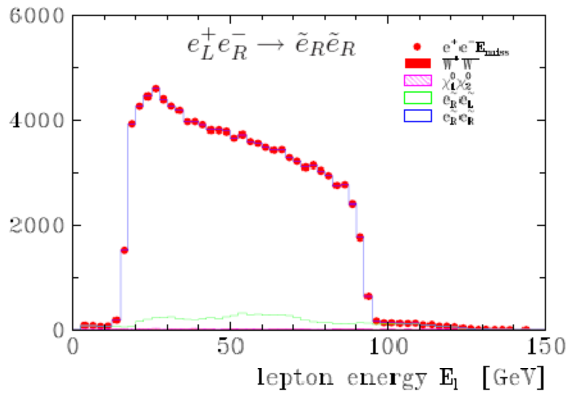
$$e^+e^- \rightarrow \tilde{\ell}_R \tilde{\ell}_R \rightarrow \ell \tilde{\chi}_1^0 \ell \tilde{\chi}_1^0$$

$\tilde{\ell}_R \rightarrow \ell + \tilde{\chi}_1^0$ flat energy spectrum

$$m_{\tilde{\ell}} = \sqrt{s}[E_+E_-]^{\frac{1}{2}}/(E_+ + E_-)$$

$$m_{\tilde{\chi}_1^0} = m_{\tilde{\ell}}[1 - 2(E_+ + E_-)/\sqrt{s}]^{\frac{1}{2}}$$

δm ~ 0.1 GeV (slepton & neutralino)



- Threshold excitation curve

characteristic β dependence, steep rise

$$\sigma(e^+e^- \rightarrow \tilde{\mu}^+\tilde{\mu}^-) \leftarrow \mathrm{P-wave}$$

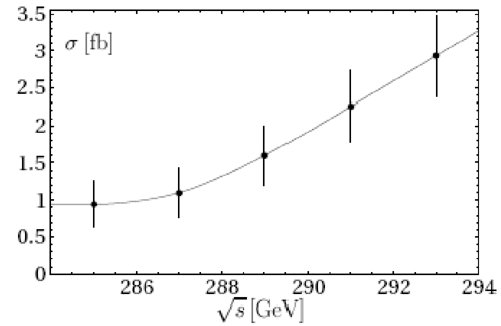
$$\sim \beta^3 \sim [1 - 4m_{\tilde{\mu}}^2/s]^{3/2}$$

$$\sigma(e^-e^- \rightarrow \tilde{e}^-\tilde{e}^-) \leftarrow \mathrm{S-wave}$$

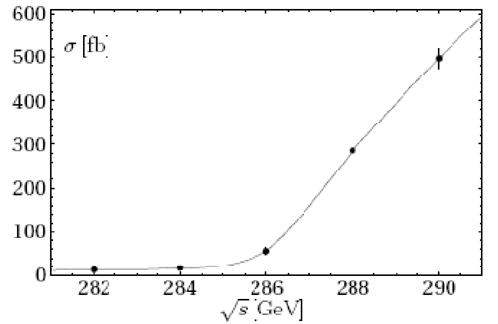
$$\sim \beta \sim [1 - 4m_{\tilde{e}}^2/s]^{1/2}$$

δm ~ 0.05 - 0.2 GeV

$e^+e^- \rightarrow (\tilde{\mu}_R^+\tilde{\mu}_R^-) \rightarrow \mu^+\mu^- + \not{E}$



$e^-e^- \rightarrow (\tilde{e}_R^-\tilde{e}_R^-) \rightarrow e^-e^- + \not{E}$



Smuon spin

Threshold production

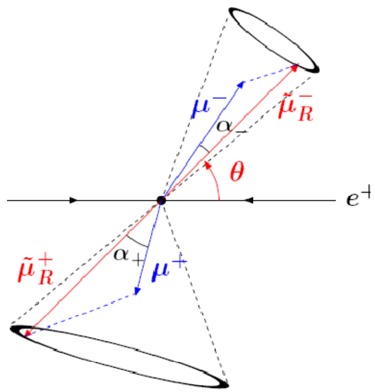
and

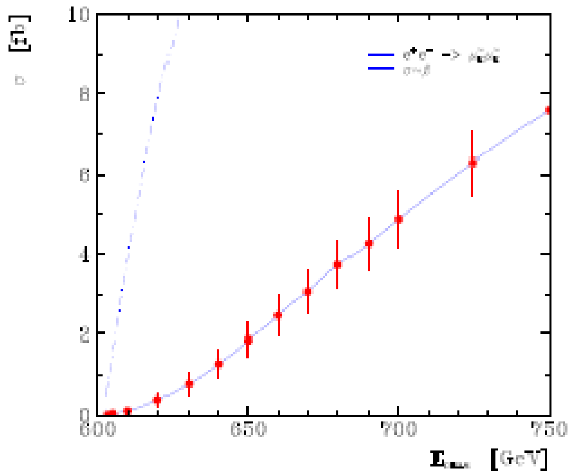
Angular distribution

$$e^+e^- \;\rightarrow\; \tilde{\mu}_R\tilde{\mu}_R \rightarrow \mu^+\tilde{\chi}_1^0\,\mu^-\tilde{\chi}_1^0$$

$$\sigma_{\tilde{\mu}_R\tilde{\mu}_R} \;\propto\; \beta^3$$

$$\mathrm{d}\sigma/\mathrm{d}\cos\theta_{\tilde{\mu}_R} \;\propto\; \sin^2\theta$$

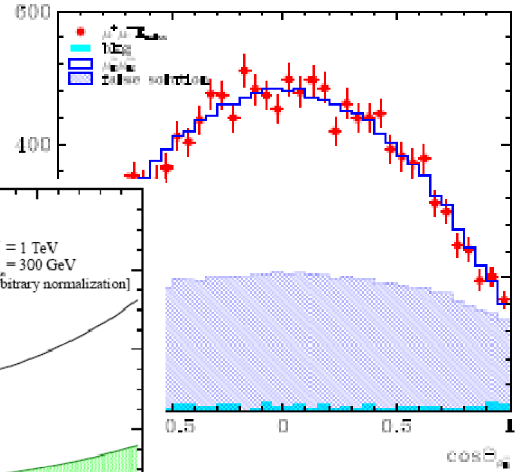


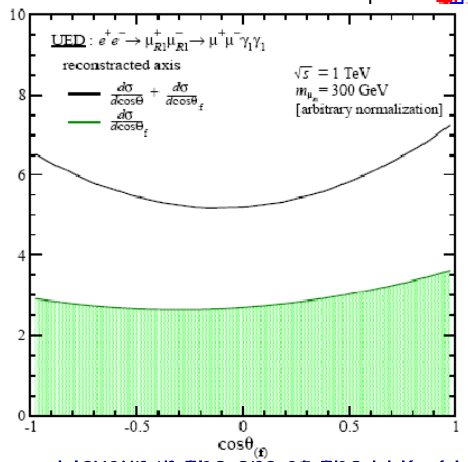


masses known: reconstruction

polar angle Θ (2-fold ambiguity)

fit: 1 - (0.98±0.02) cos²Θ





Unambiguous spin assignment

model inependent, distinct from e.g. UED

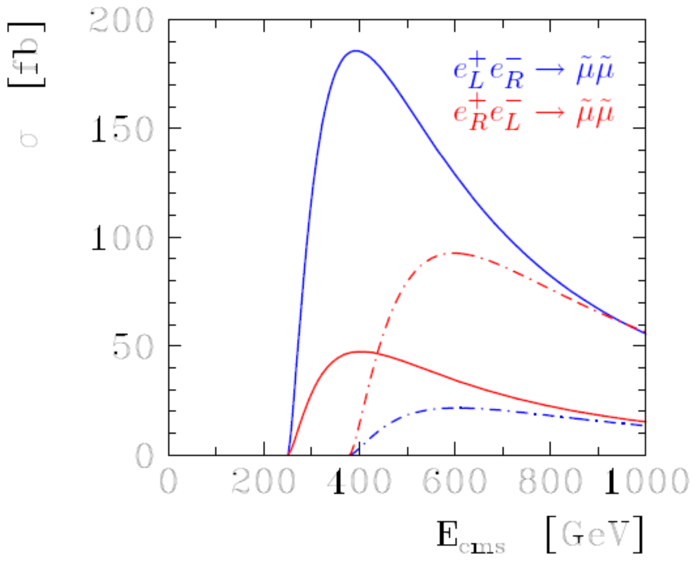
Choi et al 2006

L/R sfermion?

L/R quantum numbers via polarisation

R sfermions prefer right-handed electrons e^-_R

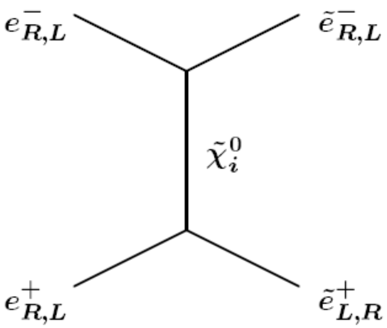
L sfermions prefer left-handed electrons e^-_L



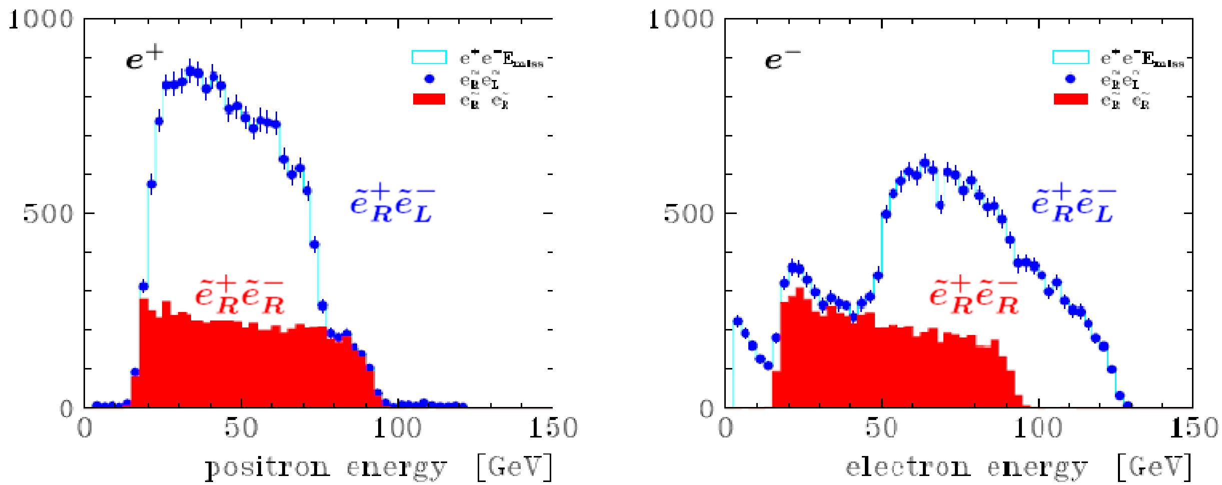
Associated selectron production

$$e^+_L e^-_L \longrightarrow \tilde{e}^+_R \tilde{e}^-_L \qquad e^+_R e^-_R \longrightarrow \tilde{e}^+_L \tilde{e}^-_R$$

different spectra for e^+ and e^- in final state



$e^+_L e^-_L \to \tilde{e}_R \tilde{e}_R,\ \tilde{e}_R \tilde{e}_L$



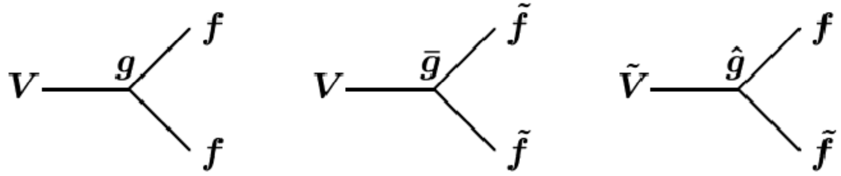
Slepton couplings

Basic element of SUSY

identical gauge and Yukawa couplings

SU(2) gauge g = Yukawa $\hat{g}$

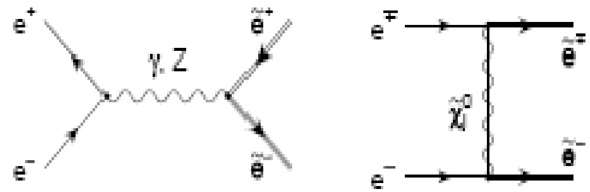
U(1) gauge g' = Yukawa $\hat{g}'$



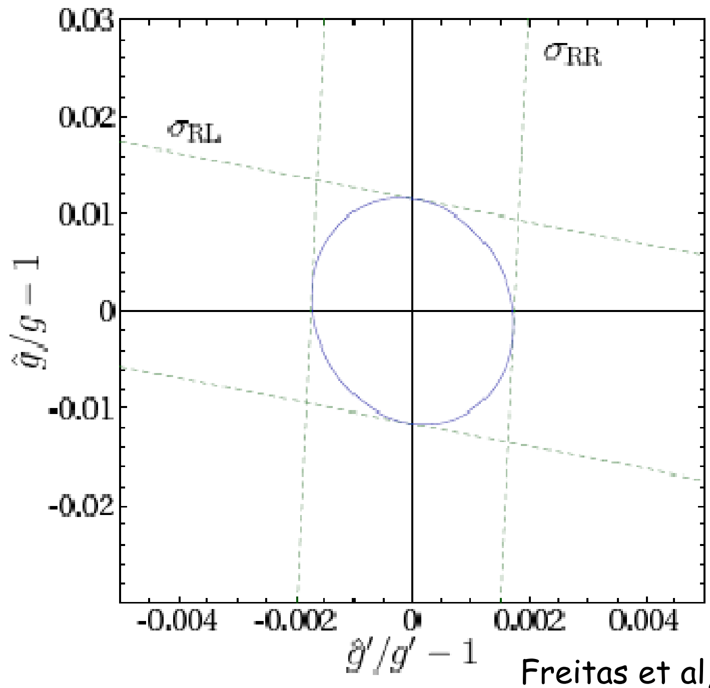
Slepton production

$$e^+e^- \to \tilde{\mu}_R\tilde{\mu}_R \quad \Rightarrow \quad \bar{g}'$$

$$e^+e^- \to \tilde{e}_R\tilde{e}_R,\ \tilde{e}_R\tilde{e}_L \quad \Rightarrow \quad \hat{g}', \hat{g}$$



SPS1 $\sqrt{s} = 500\,\text{GeV},\ \mathcal{L} = 500\,\text{fb}^{-1}$	
$e^+e^- \to \tilde{\mu}_R\tilde{\mu}_R$	$\delta\bar{g}'/\bar{g}' \simeq 1.0\,\%$
$e^+e^- \to \tilde{e}_R\tilde{e}_R$	$\delta\hat{g}'/\hat{g}' \simeq 0.2\,\%$
$e^+e^- \to \tilde{e}_R\tilde{e}_L$	$\delta\hat{g}/\hat{g} \simeq 0.7\,\%$



Freitas et al, 04

Stau mass & polarisation

Stau production

$$e^+e^- \rightarrow \tilde{\tau}_1\tilde{\tau}_1 \rightarrow \tau\tilde{\chi}_1^0\,\tau\tilde{\chi}_1^0$$

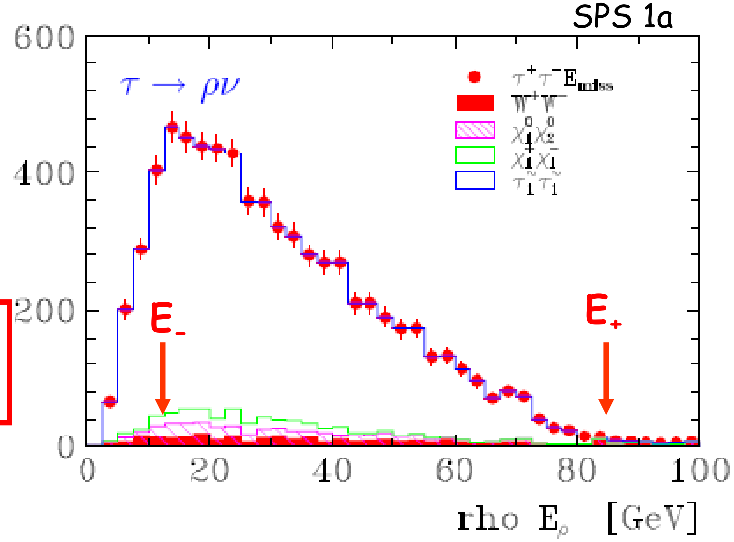
$$\tau \rightarrow \pi\nu,\ \rho\nu,\ 3\pi\nu,\ \ldots$$

flat → triangular energy spectrum

fit upper end point E_+ → m_{stau}

m_{stau} = 173 GeV

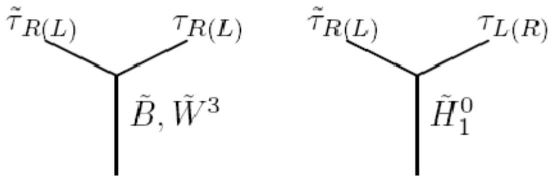
δm ~ 0.3 GeV



Mixing & polarisation

$$\tilde{\tau}_1 = \tilde{\tau}_L \cos\theta_{\tilde{\tau}} + \tilde{\tau}_R \sin\theta_{\tilde{\tau}}$$

access to couplings



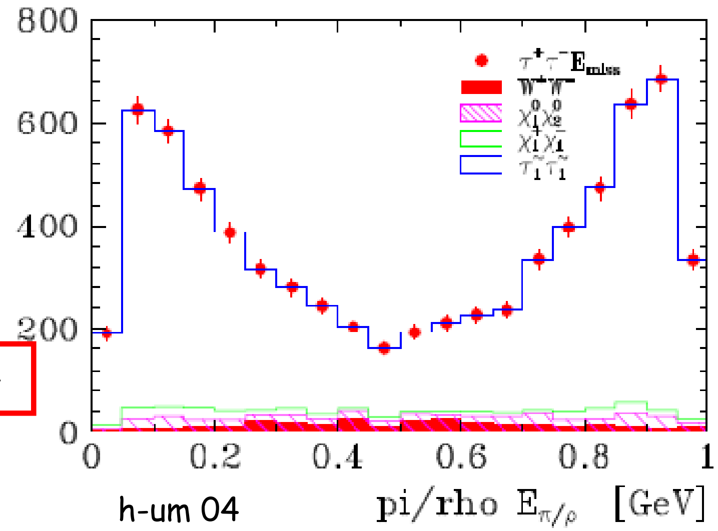
polarisation analyser

$\tau \rightarrow \rho\nu \rightarrow \pi\pi^0\nu$, $z = E_\pi/E_\rho$

$P_\tau = +1$ $dn/dz \sim (2z - 1)^2$

$P_\tau = -1$ $dn/dz \sim 2z(1 - z)$

$P_\tau = 0.98 \pm 0.04$



(S)Lepton Flavour Violation

LFV in slepton pair production

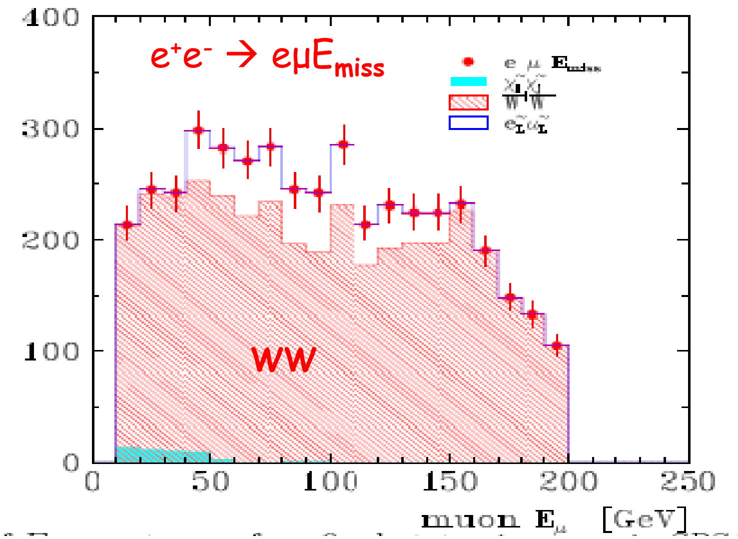
$$e^+e^- \rightarrow (\tilde{e}_L\tilde{e}_L,\ \tilde{\mu}_L\tilde{\mu}_L) \rightarrow e\tilde{\chi}_1^0\,\mu\tilde{\chi}_1^0$$

$$e^+e^- \rightarrow (\tilde{\tau}_1\tilde{\tau}_1,\ \tilde{\mu}_L\tilde{\mu}_L) \rightarrow \tau\tilde{\chi}_1^0\,\mu\tilde{\chi}_1^0$$

Seesaw mechanism to generate neutrino masses m_ν
LR extension: ν_R singlet fields and superpartners added to MSSM

sensitivity $\sigma_{LFV} \sim 0.1\text{-}1$ fb

→ Majorana mass scale $M_R \sim 10^{13\text{-}14}$ GeV
SUSY seesaw induces SM LFV processes
→ radiative decay $Br(\mu \rightarrow e\gamma) \sim 10^{-12}$

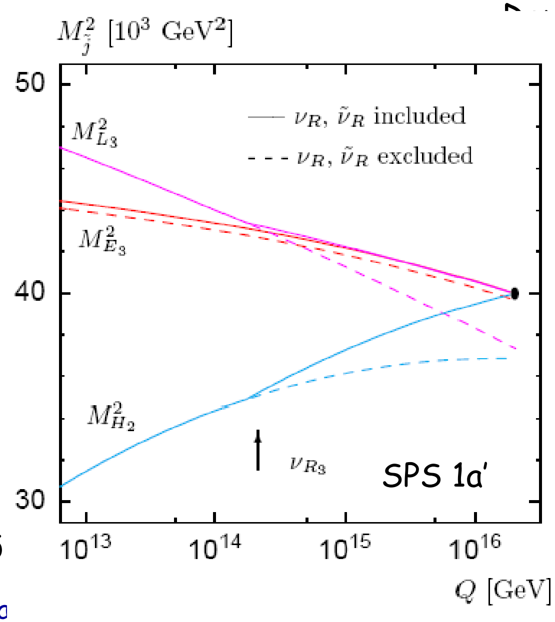


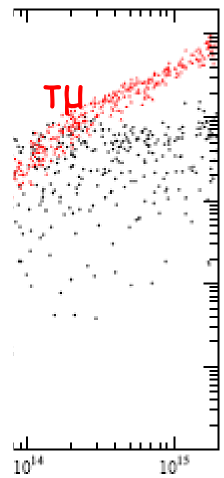
isch et al 04

Massive neutrinos affect RGEs of sleptons

flavour off-diagonal terms with large Yukawa couplings for 3rd generation
kink in evolution of L_3, H_2

$M(\nu_{R3}) = (5.9 \pm 1.6)\ 10^{14}$ GeV





Blair et al 05

Neutralino/chargino masses

Neutralino production $\delta m(X^0_2)$ ~ 0.3 GeV

$$e^+e^- \;\rightarrow\; \tilde{\chi}^0_2\tilde{\chi}^0_2 \rightarrow \ell\bar{\ell}\tilde{\chi}^0_1\;\ell'\bar{\ell}'\tilde{\chi}^0_1$$

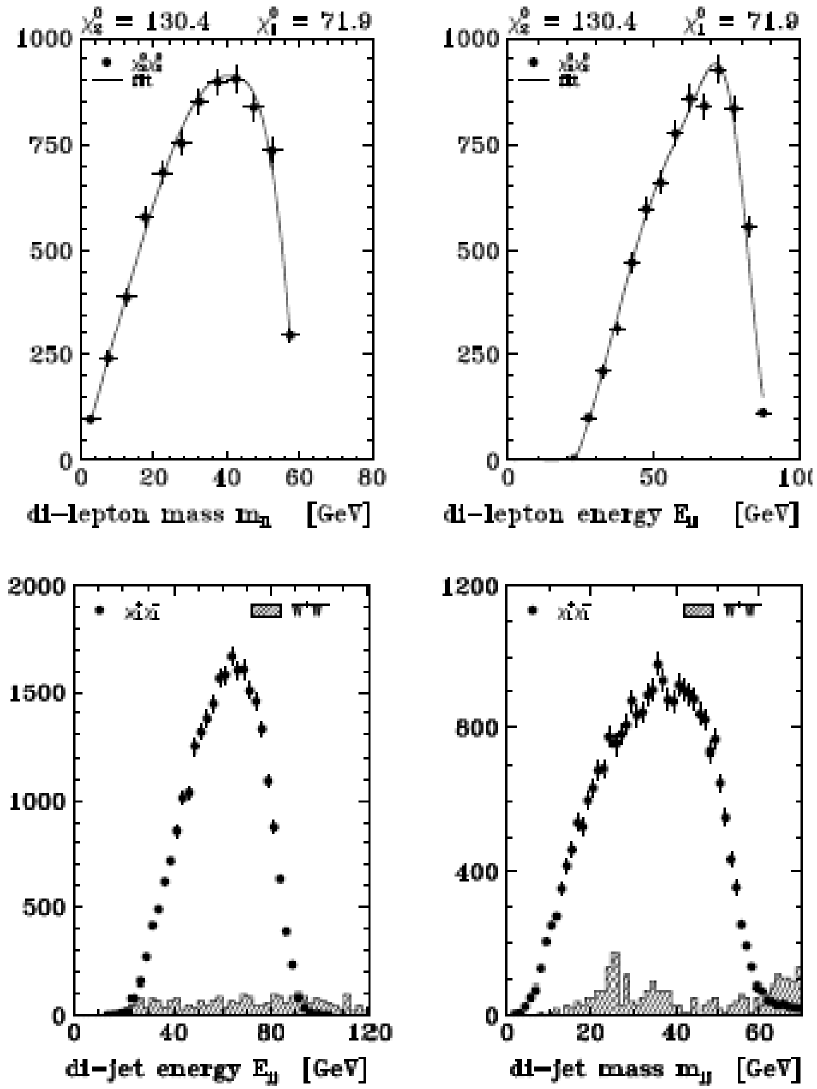
$$\text{max } m_{\ell\ell} \Rightarrow \Delta m(\tilde{\chi}^0_2 - \tilde{\chi}^0_1)$$
$$E_{\ell\ell} \Rightarrow m_{\tilde{\chi}^0_2}\ \&\ m_{\tilde{\chi}^0_1}$$

Chargino production $\delta m(X^\pm_1)$ ~ 0.2 GeV

$$e^+e^- \;\rightarrow\; \tilde{\chi}^+_1\tilde{\chi}^-_1 \rightarrow \ell\nu\tilde{\chi}^0_1\;q\bar{q}'\tilde{\chi}^0_1$$

$$\text{max } m_{di-jet} \Rightarrow \Delta m(\tilde{\chi}^\pm_1 - \tilde{\chi}^0_1)$$
$$E_{di-jet} \Rightarrow m_{\tilde{\chi}^\pm_1}\ \&\ m_{\tilde{\chi}^0_1}$$

Many reactions to get the mass of the lightest neutralino very accurately! $\delta m(X^0_1)$ ~ 0.05 GeV



H-UM, Blair 99

Chargino mixing & spin

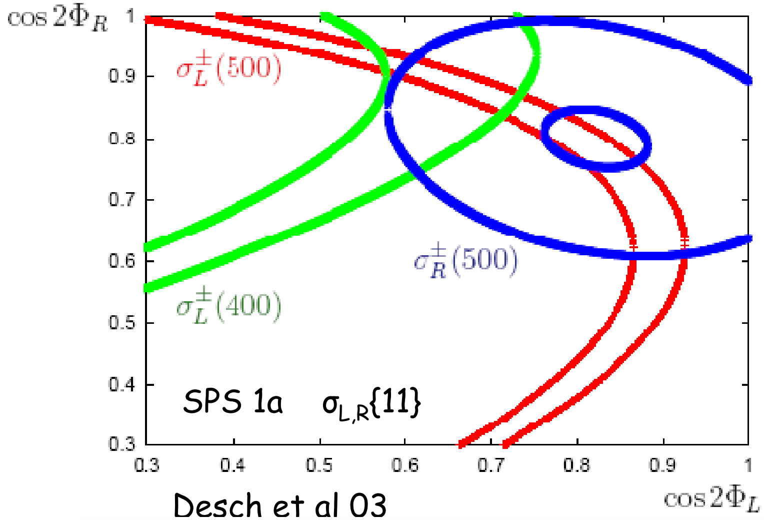
Chargino sector Dirac particle J=1/2

$$e^+e^- \to \tilde{\chi}_i^+ \tilde{\chi}_j^-$$
$$\tilde{\chi}_i^\pm \to W^{(*)} \tilde{\chi}_1^0$$

Mixings

$$\tilde{\chi}^\pm_{1\,L,R} = +\cos\phi_{L,R}\tilde{W}^\pm_{L,R} + \sin\phi_{L,R}\tilde{H}^\pm_{L,R}$$
$$\tilde{\chi}^\pm_{2\,L,R} = -\sin\phi_{L,R}\tilde{W}^\pm_{L,R} + \cos\phi_{L,R}\tilde{H}^\pm_{L,R}$$

$\cos 2\Phi_{L,R}$ from $\sigma_{L,R}\{ij\}$ at different energies



Desch et al 03

Spin

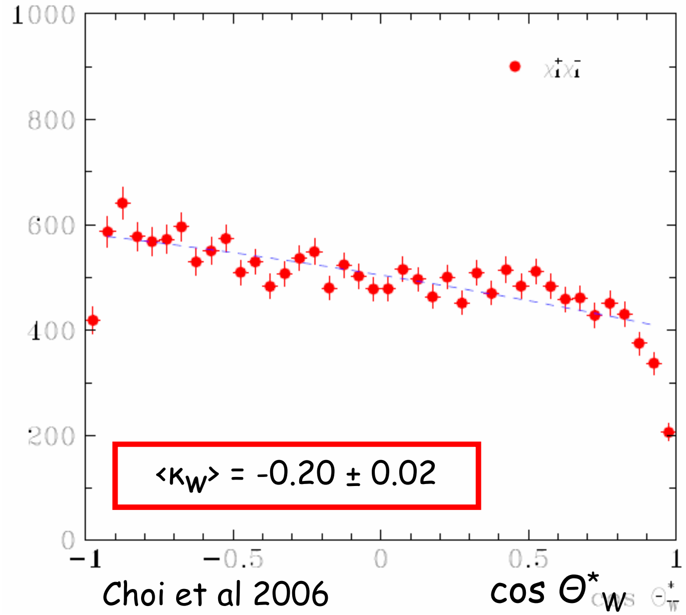
prod angle: no discrimination, 4-fold ambiguity

polarisation effects in decay → spin 1/2

angular distribution of W (→lν) in $X^\pm_1$ restframe

$$\frac{1}{d\Gamma}\frac{\Gamma}{d\cos\theta^*_{W\pm}}[\tilde{\chi}_1^\pm \to W^\pm\tilde{\chi}_1^0] = \frac{1}{2}(1+\langle\kappa_{W\pm}\rangle\cos\theta^*_{W\pm})$$

CP symmetry: $\langle\kappa_W\rangle = -0.216$



Choi et al 2006

Sleptons in cascade decays

Decay chains à la LHC

$$\tilde{\chi}_2^0\tilde{\chi}_2^0 \to \tilde{\ell}_R\ell\ \tilde{\ell}'_R\ell' \to \ell\ell\tilde{\chi}_1^0\ \ell'\ell'\tilde{\chi}_1^0$$

signature: 4 leptons + E_{miss}

kinematics of cascade decay provides access to intermediate slepton

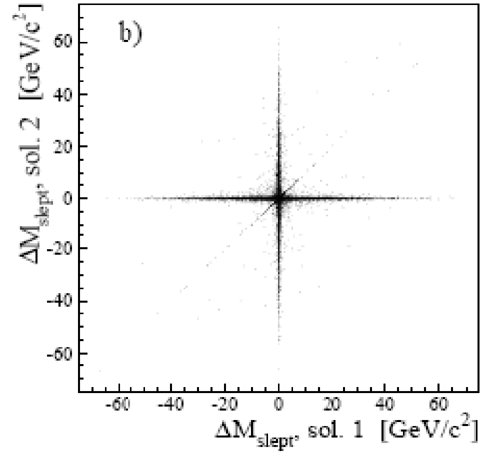
2-fold ambiguity for mass solutions

➔ **extremely narrow mass peak**

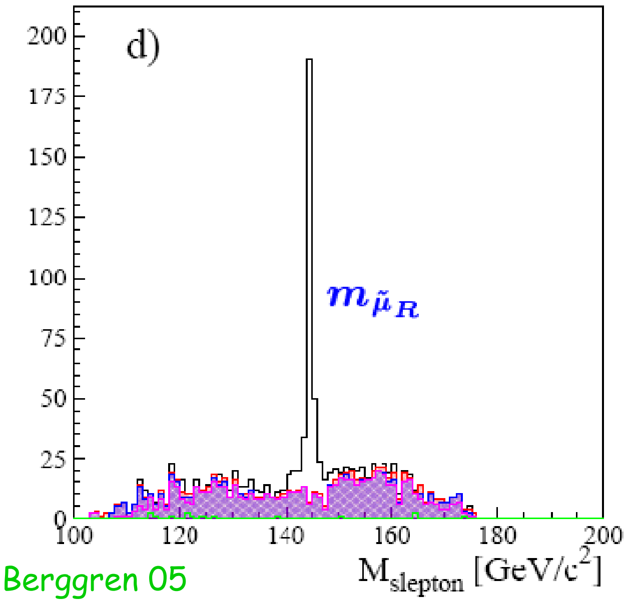
$\delta m/m \sim 5\cdot 10^{-5}$

Similarly: L-selectron reconstruction

$$e^-e^- \to \tilde{e}_L^-\tilde{e}_L^- \to e^-\tilde{\chi}_1^0\ e^-\tilde{\chi}_2^0 \to e^-\tilde{\chi}_1^0\ e^-\ell\bar{\ell}\tilde{\chi}_1^0$$



$$m_{\tilde{\mu}_R} = 174.73 \pm 0.009\ \text{GeV}$$



Berggren 05

Stop mass & mixing

Stop production

$$e^+e^- \rightarrow \tilde{t}_1 \tilde{t}_1$$

$$\tilde{t}_1 \rightarrow c\,\tilde{\chi}_1^0 \qquad m_{\tilde{t}_1} < m_t + m_{\tilde{\chi}_1^0}$$

lightest squark in many scenarios,
difficult to detect at LHC

signature: 2 c-quarks + E_{miss}

Mixing

$$\tilde{t}_1 = \tilde{t}_L \cos\theta_{\tilde{t}} + \tilde{t}_R \sin\theta_{\tilde{t}}$$

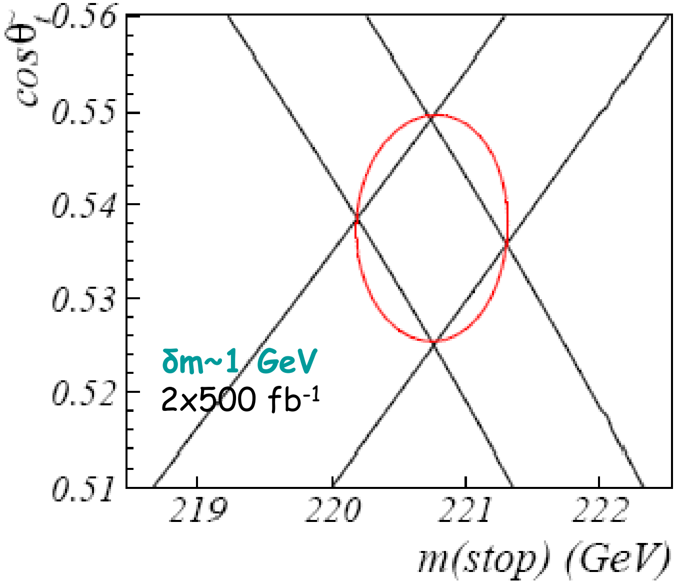
polarised cross sections

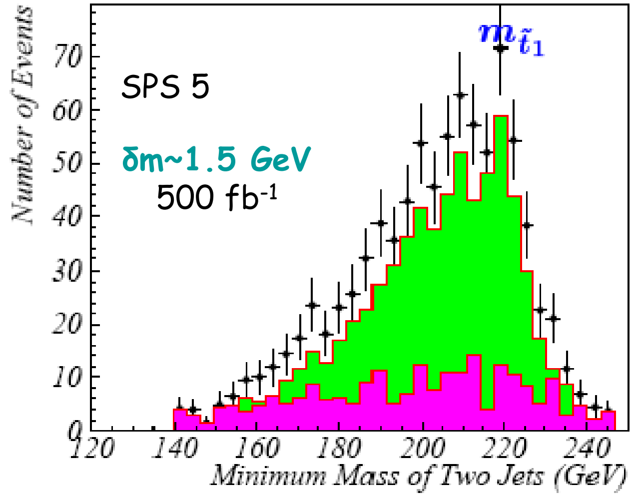
$$\sigma_{e_L^+ e_R^-},\ \sigma_{e_R^+ e_L^-} \Rightarrow m_{\tilde{t}_1},\ \cos\theta_{\tilde{t}}$$

Minimal mass

reconstructed from kinematics, momentum correlations, using m_X

➔peak at m_{stop}





Finch et al 04

SPS 1a′ spectrum from LHC+ILC

Particle	Mass	"LHC"	"ILC"	"LHC+ILC"
h^0	116.0	0.25	0.05	0.05 ←
H^0	425.0		1.5	1.5
$\tilde{\chi}_1^0$	97.7	4.8	0.05	0.05 ←
$\tilde{\chi}_2^0$	183.9	4.7	1.2	0.08 ←
$\tilde{\chi}_4^0$	413.9	5.1	$3-5$	2.5
$\tilde{\chi}_1^\pm$	183.7		0.55	0.55
$\tilde{e}_R$	125.3	4.8	0.05	0.05 ←
$\tilde{e}_L$	189.9	5.0	0.18	0.18
$\tilde{\tau}_1$	107.9	$5-8$	0.24	0.24
$\tilde{q}_R$	547.2	$7-12$	–	$5-11$
$\tilde{q}_L$	564.7	8.7	–	4.9 ←
$\tilde{t}_1$	366.5		1.9	1.9
$\tilde{b}_1$	506.3	7.5	–	5.7 ←
$\tilde{g}$	607.1	8.0	–	6.5 ←

SPA project, EPJC 46 (2006) 43

Coherent LHC+ILC analysis:

- complementary contributions spectrum completed
- superior to sum of individual analyses
- accuracy increased by 1-2 orders of magnitude

Goal:

reconstructing fundamental supersymmetric theory starting from expt. observations

Challenge:

experimental accuracy matched by theory?

Extracting Lagrange parameters

Global fit simulated 'data' from LHC & ILC

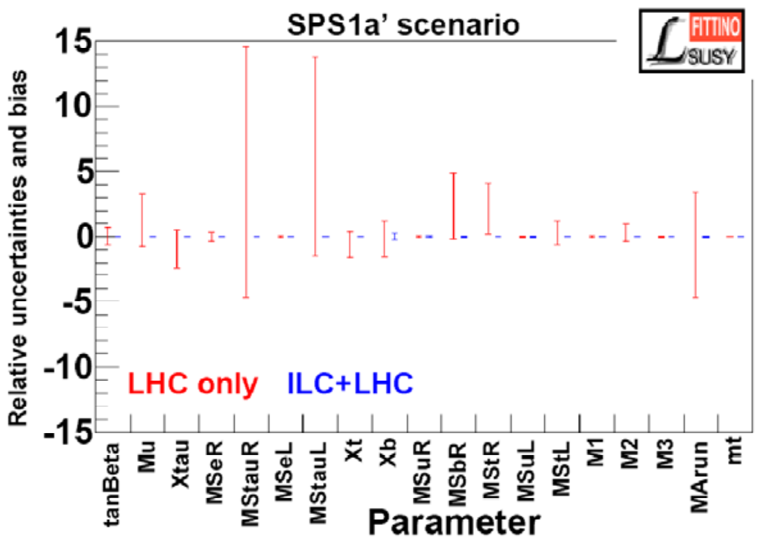
http://spa.desy.de/spa/

input: masses, edges, x-sects, BRs, mixings …
~120 observables incl. realistic error correlations

tools: spectrum calculators, RGE's, HO x-sects, SLHA, fitting programs,
consistent renorm. scheme

Results SPS 1a' high precision

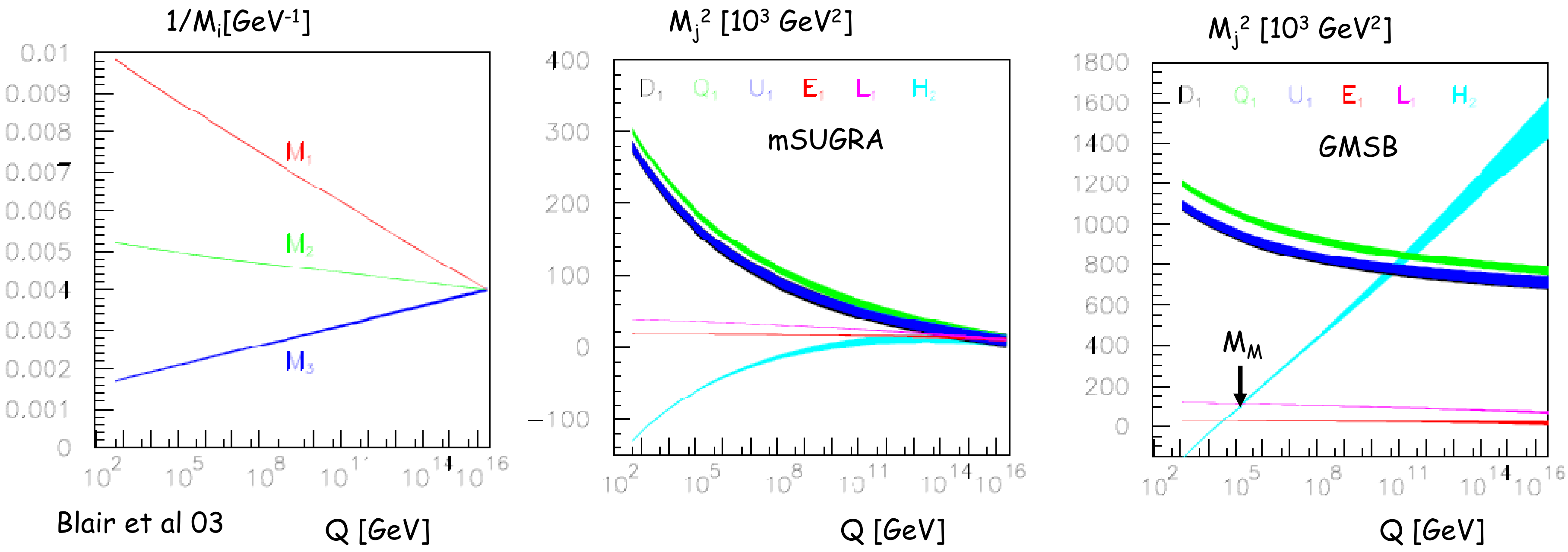
LHC alone not able to constrain
most parameters



Parameter	SPS1a′ value	Fit error [exp]	LHC only [exp]
M_1	103.3	0.1	8
M_2	193.2	0.1	132
M_3	571.7	7.8	10
μ	396.0	1.1	811
M_{L_1}	181.0	0.2	13
M_{E_1}	115.7	0.4	39
M_{L_3}	179.3	1.2	1370
M_{Q_1}	525.8	5.2	10
M_{D_1}	505.0	17.3	18
M_{Q_3}	471.4	4.9	425
m_A	372.0	0.8	
A_t	–565.1	24.6	550
$\tan\beta$	10.0	0.3	6.7

High-scale extrapolation

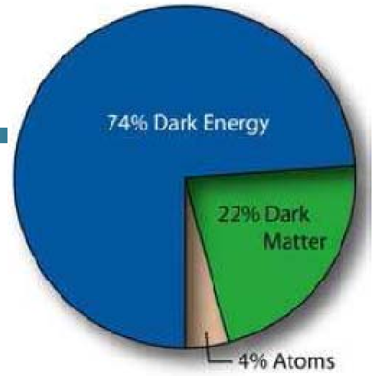
- Universality of gaugino & scalar mass parameters in mSUGRA



- Evolution in GMSB distinctly different from mSUGRA
- Bottom-up evolution of Lagrange parameters provides high sensitivity to SUSY breaking schemes

LHC+ILC: Telescope to Planck scale physics

Dark matter & colliders



Cold dark matter in Universe $\Omega_{DM} \approx 22\%$

$\Omega_{DM}h^2 = 0.105 \pm 0.008$ **WMAP**

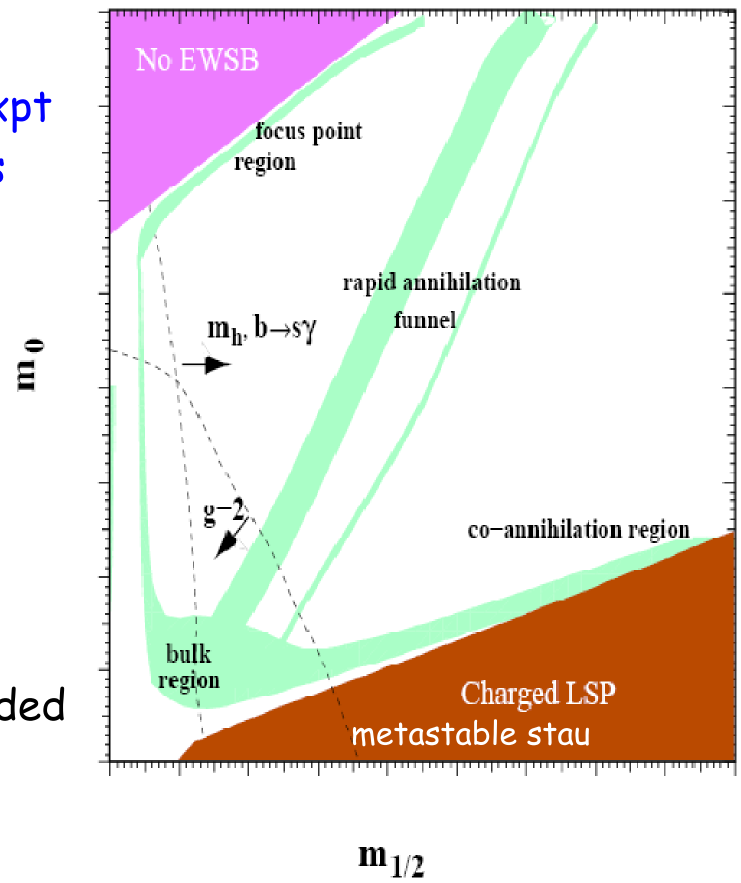
→ $\pm$ 0.002 **Planck**

Understanding nature of cold dark matter:

- direct detection DM particle in astrophysical expt
- precise measurement of mass & spin at colliders
- relic density calculation

  $\Omega_X h^2 \sim 3 \cdot 10^{-27} cm^3 s^{-1} / \langle \sigma v \rangle$

  typical WI annihilation cross section



Candidates: neutralino, gravitino, sneutrino, axino
KK states, …

Formation:

freeze out of thermal equilibrium $f\bar{f} \leftrightarrow \tilde{\chi}\tilde{\chi}$

in general Ω_X » 0.2, annihilation mechanism needed

thermal production $g\tilde{g} \to g\tilde{G},\ q\tilde{g} \to q\tilde{G} \ldots$

late decays $\tilde{\tau}_1 \to \tau\tilde{G}$

Neutralino dark matter

SPS 1a' 'bulk region'

annihilation through slepton exchange

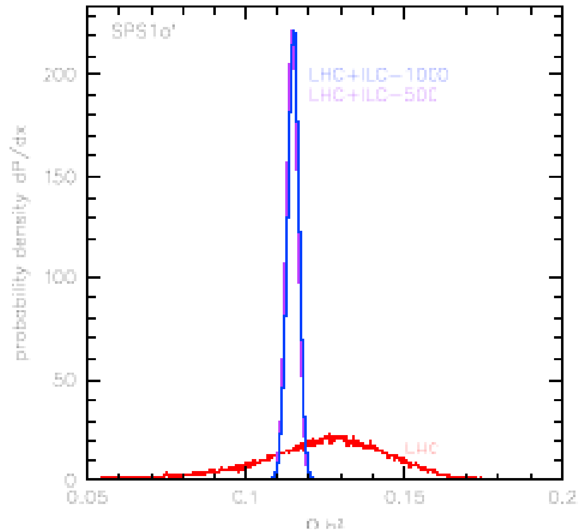
$\chi\chi \to \tau\tau$, bb

$\sigma_{\chi\chi}$ depends on light slepton masses & couplings

LHC: 'a posteriori' fix of unconstrained parameters

LHC+ILC: precision ~1-2%, matches WMAP/Planck expts

➔ **Reliable prediction for direct neutralino-proton detection cross section**



LCC2 'focus point region'

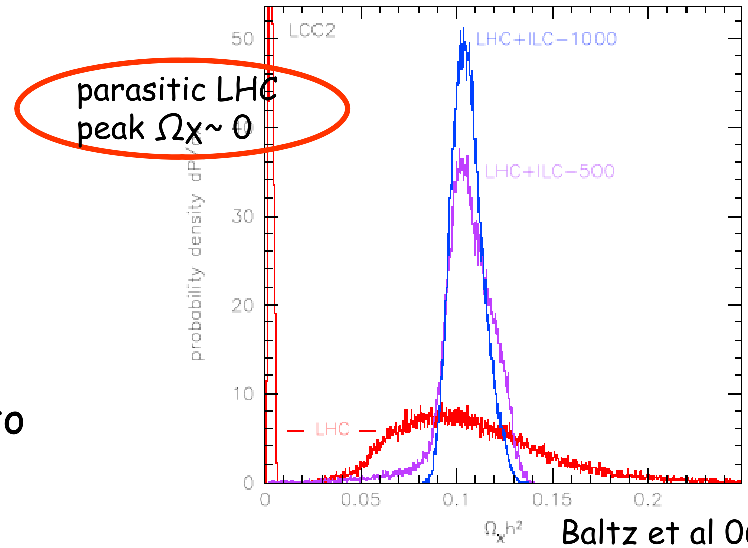
heavy sfermions, light gauginos

annihilation $\chi\chi \to$ WW, ZZ

$\sigma_{\chi\chi}$ depends on M_1, M_2, μ, $\tan\beta$

LHC: gluino decays provide not enough constraints to solve neutralino matrix

LHC+ILC: ~10% precision on relic abundance



Baltz et al 06

Gravitino dark matter

Gravitino mass set by SUSY breaking scale F of mediating interaction

$m_{3/2} = F/\sqrt{3} \cdot M_P$ Planck scale $M_P = 2.4 \cdot 10^{18}$ GeV

in general free parameter depending on scenario TeV … eV

most interesting: gravitino LSP, stau NLSP $m_{3/2} = O(10\text{-}100 \text{ GeV})$

Dominant decay $\tilde{\tau} \longrightarrow \tau \tilde{G}$ **gravitational coupling, lifetime sec - years**

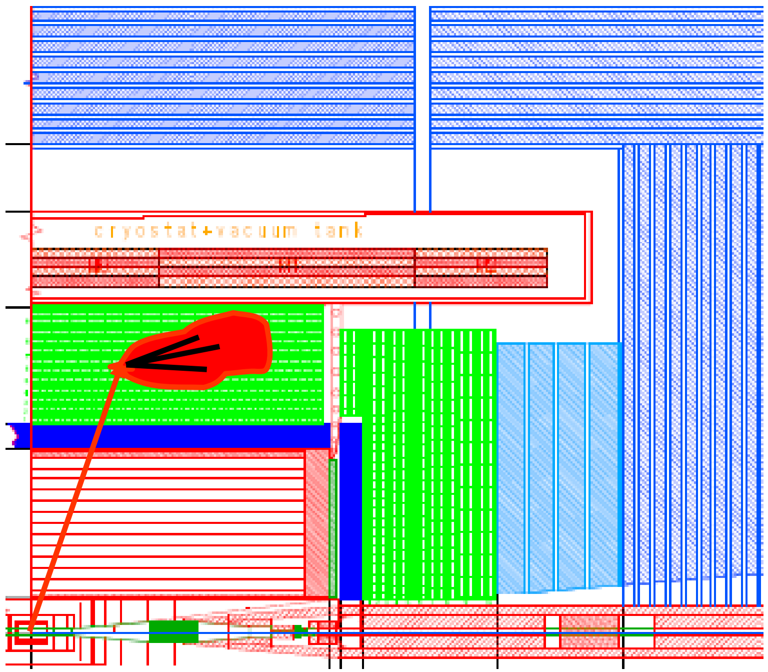
$$\Gamma_{\tilde{\tau}\to\tau\tilde{G}} = \frac{1}{48\pi M_P^2}\frac{m_{\tilde{\tau}}^5}{m_{\tilde{G}}^2}\left[1 - \frac{m_{\tilde{G}}^2}{m_{\tilde{\tau}}^2}\right]^4$$

Detecting metastable staus & gravitinos

- identify & record stopping stau → stau mass
- wait until decay → stau lifetime
- measure τ recoil spectra → gravitino mass

$$E_\tau = (m_{\tilde{\tau}}^2 - m_{\tilde{G}}^2)/2\, m_{\tilde{\tau}}$$

- rare radiative decays → gravitino spin
  - γ-τ correlations in $\tilde{\tau} \longrightarrow \tau\gamma\tilde{G}$



LHC detectors not appropriate

Gravitino not detectable in astrophysical expts

Gravitino dark matter

GDM ε scenario $m_0 = m_{3/2} = 20$ GeV, $M_{1/2} = 440$ GeV

ILC case study L=100 fb^{-1} @ 500 GeV (<1 year data taking)

- **Prolific stau production**

  $$m_{\tilde\tau} = 157.6 \pm 0.2 \text{ GeV}$$

- **Lifetime measurement**

  $$t_{\tilde\tau} = (2.6 \pm 0.05) \cdot 10^6 \text{ s}$$

  $$m_{\tilde\tau},\, t_{\tilde\tau} \Rightarrow m_{\tilde G} = 20 \pm 0.2 \text{ GeV}$$

- **Decay spectrum**

  $$m_{\tilde G} = 20 \pm 4 \text{ GeV}$$

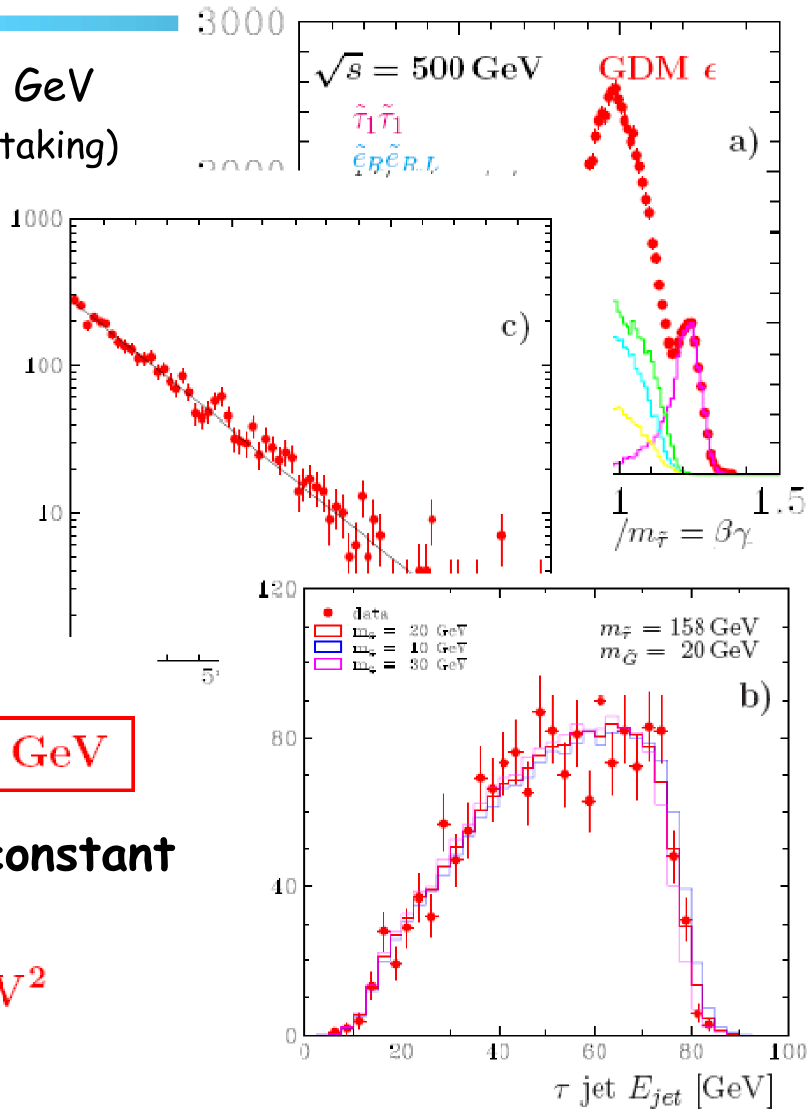
  $$m_{\tilde\tau},\, t_{\tilde\tau},\, m_{\tilde G} \Rightarrow M_P = (2.4 \pm 0.5) \cdot 10^{18} \text{ GeV}$$

  ➔ **Access to Planck scale / Newton's constant**

- **SUSY breaking scale**

  $$F = \sqrt{3}\, m_{\tilde G} M_P = (8.3 \pm 0.1) \cdot 10^{19} \text{ GeV}^2$$

- **Unique test of supergravity:**
  gravitino = superpartner of graviton



H-U M, EPJC 48 (2006) 15

Conclusions

- Excellent identification of flavour, resp. particle properties, needed in order to explore new discoveries.
- High precision measurements at the ILC will complement the physics programme of the LHC and will play a crucial role to identify the underlying theory.
- Both colliders, the LHC and ILC, are essential if we want to make progress in understanding electroweak symmetry breaking, unification of interactions suggested by supersymmetry and the connection of particle physics with cosmology.